A Novel Coding Technique To Minimise The Transmission Bandwidth And Bit Error Rate In DPSK

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Summary

We propose a novel coding technique that aims to reduce the Transmission Bandwidth (B_T) and Bit Error Rate (BER) vis-à-vis Conventional Differential Phase Shift Keying (CDPSK) in digital band pass transmission. In CDPSK two successive bits are used for encoding. The proposed method encodes information with respect to the consecutive two bits $b(t-T_b)$ and $b(t-2T_b)$. The encoded data is keyed on to the phase. The received signal is demodulated by using the present phase $\phi(t)$ and the two phases $\phi(t-T_b)$ and $\phi(t-2T_b)$. Comparative analysis between the two techniques reveals the advantages of the proposed technique.

Key Words

Encoding, decoding, modulation, demodulation, non-coherent detection, differential encoding, phase, delay, band pass channel, data rates, Bit Energy(E_b), Transmission Bandwidth(B_T), Bit Error rate(BER), InterSymbol Interference(ISI), fading, Additive White Gaussian Noise, BPSK, DPSK.

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1Introduction

Digital modulation is ideally suited to multitude of communication applications, including both cable and wireless systems. Applications include the following: (1) relatively low speed voice band data communication modems, such as those found in most personnel computers; (2) high speed data transmission systems, such as broad band digital subscriber lines (DSL); (3) digital microwave and satellite communication systems; and (4) cellular telephone Personal Communication Systems(PCS)[1].

There are number of binary modulation schemes available to the designer of a digital communication system for data transmission over a band pass channel. Every scheme offers system trade-offs of its own. However, the final choice made by the designer is determined by available primary communication resources such as channel bandwidth and transmitted power.

PCM Telemetry systems are best models for analysis of encoding techniques because they have data rates varying from very low to very high in the same channel. The scheme envisaged in this paper overcomes most of the disadvantages in CDPSK transmission, resulting in superior transmission efficiency and much lower error rates.

The scheme can be easily implemented using commercially available interferometers and high speed logic gates.

We now discuss the basic performance criteria in the CDPSK and the variations in the Novel DPSK to highlight the benefits. Modulation schemes to be developed for overall improvements in the link performance will be taken up as future work.

1.1 Organization of the Paper

The rest of the paper is organized as follows: section 2 describes the design aspects; section 3 makes an understanding of the Problem Methodology and Solution; section 4 deals with experimental results; section 5 concludes the results of experiments and future scope of Digital Communications coding and section 6, the final section of the paper, provides References.

2 Comparative study between CDPSK and Novel DPSK

Several factors influence the choice of digital modulation schemes. A desirable modulation scheme provides low bit error rates at low received signal to noise ratios, performs well in multipath and fading conditions and occupies a minimum of Bandwidth. Existing modulation schemes do not simultaneously satisfy all these requirements. Some modulation schemes are better in terms of the bit error rate performance, while others are better band width efficient. Depending upon the demands of the particular application, tradeoffs are made when selecting a digital modulation [2].

2.1 Existing scheme (CDPSK)

The error performance and channel bandwidth requirement of Binary Phase Shift Keying (BPSK) are superior to either Binary Amplitude Shift Keying (BASK) or Binary Frequency Shift Keying (BFSK). In BPSK the information is keyed on to the phase. i.e.,

$$s(t) = +\sqrt{E_b}\phi(t) \text{ for symbol 1}$$

$$= -\sqrt{E_b}\phi(t) \text{ for symbol 0}$$

Where

$$\phi(t) = \sqrt{\frac{2}{T_b}} cos w_c t$$

E_b = Signal energy per bit in Joules

T_b = Bit duration in seconds

$w_c t$ = Carrier phase in radians

The non-coherent detection which uses envelop detector, fails to demodulate the carrier in BPSK system as the amplitude of the incoming BPSK signal goes negative for symbol 0, and coherent method, which requires phase locked local oscillator and is complicated in design. Pseudo PSK technique which combines differential encoding with PSK is known as Differential Phase Shift Keying (DPSK). A schematic arrangement of generating and detecting DPSK signal is shown in figures 2a and 2b.

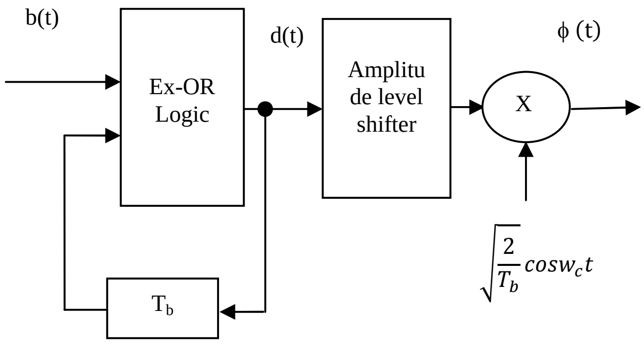

Figure2a Block diagram of a CDPSK encoder

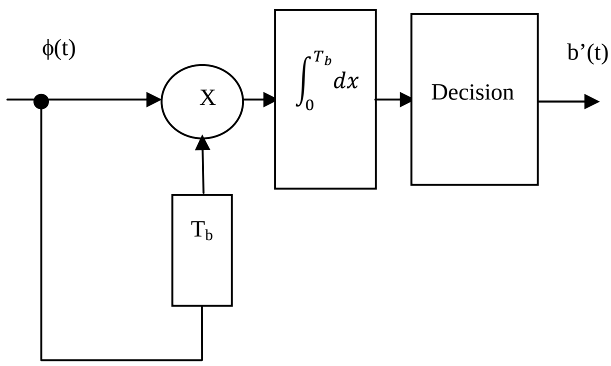

Figure2b Block diagram of a CDPSK decoder

Non-coherent version of DPSK modulation scheme is better in terms of the B_T performance, but at the same time increases the required E_b/N_o for a particular BER[3][4].

2.2 Proposed Scheme (Novel DPSK)

In this section we explain the design and functionality of the Novel DPSK. The encoder consists of delay technique for generating the encoded symbols. There are two delay loops. The reference bit is subjected to one bit delay in the first loop and further one more bit delay in the second loop. Effectively both the delay loops and the original reference bit are Ex-ORed so as to convert the raw binary sequence b(t) in to a differentially encoded sequence d(t). This sequence is amplitude level encoded and then modulates a carrier wave of frequency f_c, thereby producing the desired DPSK signal. The relation between the binary sequence b(t) and its differentially encoded version is given as

$$d(t) = b(t) \oplus d(t - T_b) \oplus d(t - 2T_b) \quad (1)$$

And the phase of the generated DPSK signal is given by

$$\phi(t) = \pi \text{ for } d(t) = \text{symbol } 0$$
$$= 0 \text{ for } d(t) = \text{symbol } 1$$

The received DPSK signal and the delayed versions by the time intervals T_b and $2T_b$ are multiplied using two product modulators and then subjected to an integrator.

The polarity of the integrator in put

- is positive when the number of inputs to the multiplier having phase as π is even.
- is negative when the number of inputs to the multiplier having phase as π is odd.

The out put of the integrator is applied to a decision device (decoded bit stream), which compares the input with a decision level of zero volts and can reconstruct the binary sequence by assigning a symbol 0 for negative input and a symbol 1 for positive input.

2.3 System Requirements

System is implemented using: Exclusive OR logic circuit; Shift registers for providing one bit delay; Amplitude level shifter; Product modulators; Oscillator; Integrator; and a decision device. The block schematic of the encoder and the decoder for the proposed coding technique are shown in figures 2c and 2d respectively.

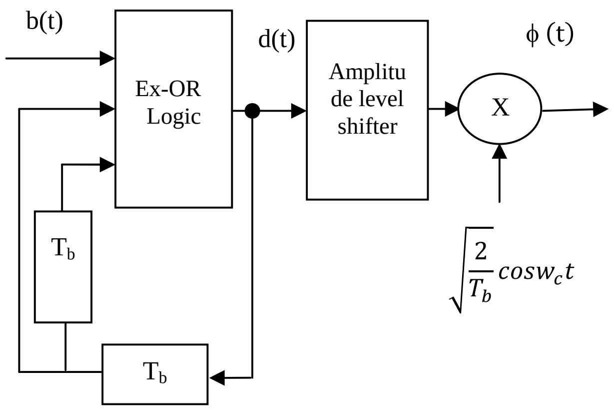

Figure2c Illustration of the scheme to generate DPSK signal

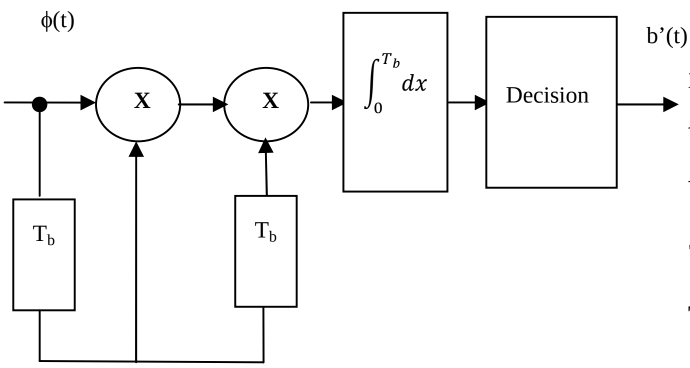

Figure2d Illustration of the scheme to demodulate the DPSK signal

3 Statement of the Problem

Present digital modulation schemes, such as BPSK and CDPSK offers less Bandwidth with high BER or other way round, with the result that transmission is not achieved according to the flexible specifications of the users. This paper proposes a scheme of encoding and decoding to achieve better Bandwidth and BER performance for efficient transmission.

3.1 Problem Methodology and Solution

This section deals mathematically with emphasis on Bandwidth and BER performance improvement to confirm on the original postulations.

3.1.1 Bandwidth Reduction Analysis

As new emerging broadband applications demand reliable wireless communication at lower transmission bandwidth and power there is a need to develop more efficient encoding methods.

In the proposed method the binary data information is contained in the differential of three successive signaling elements. Therefore the symbol can be said to have three bit duration, $3T_b$, i.e., Symbol duration $T_s = 3T_b$

Therefore

$$B_T = \frac{2}{T_s} = \frac{2}{3T_b} = \frac{2}{3} f_b \quad (2)$$

Where

f_b = bit rate

It is interesting to note from equation 2 that the Novel DPSK provides atleast 33% saving in channel bandwidth compared to CDPSK.

3.1.2 BER improvement Analysis

The rapid development of the next generation digital wireless communication system calls for better error performance to combat channel impairments such as multiple access interferences and InterSymbol Interferences (ISI). BER expression accounts for the effects of ISI, Interchannel Interference, frequency-selective fading, time-selective fading, and additive noise. In high bit rate transmission, when the signal bandwidth is larger than the channel coherent bandwidth, the channel exhibits frequency selective fading, the channel introduces propagation delay dispersion, resulting in ISI. In the absence of ISI, the output of the demodulator at the end of the n^{th} symbol interval is

$$r_n = x_n + n_n \qquad (3)$$

Where

the desired signal component

$x_n = +\sqrt{E_b}$, when symbol 1 is sent

$= -\sqrt{E_b}$, when symbol 0 is sent

And the noise component

n_n = Gaussian random variable with zero mean and variance $\frac{N_0}{2}$ in Watts per Hz.

The error performance of DBPSK when operating over an AWGN channel is given [5][6].

$$\text{BER} = \frac{1}{2} e^{K\frac{E_b}{2N_0}} \qquad (4)$$

Where

E_b = Bit Energy in joules

N_o = Thermal noise in 1Hz of bandwidth in watts per Hz.

K= 2 for CDPSK

K= 3 for proposed DPSK

Here we find that the BER improvement is atleast one order. It may increase the error propagation, since the correlation among the bits in the binary sequence increases in this system.

4 Experimental Results

We present the results of series of experiments conducted to demonstrate the proposed method. For the data stream b(t) applied to the input of the encoder is 1 0 1 1 0 1 1. Table 4a, 4c, 4e, 4g show the phase of the DPSK waveform generated using the proposed encoding technique for all possible combinations of the initial conditions (00, 01, 10, 11). Table 4b, 4d, 4f and 4h show the phase of the decoded DPSK waveform and converted binary stream.

Table 4a: Choice of the initial bits: 00

b(t)	d(t-T_b)	d(t-2T_b)	d(t)	ϕ(t)
1	0	0	1	0
0	1	0	1	0
1	1	1	1	0
1	1	1	1	0
0	1	1	0	π
1	0	1	0	π
1	0	0	1	0

From the table above the carrier phase shift introduced corresponding to the data stream is

π π 0 0 0 0 π π 0

Table 4b

ϕ(t)	ϕ (t-T_b)	ϕ(t-2T_b)	Sign	b'(t)
0	π	π	+	1
0	0	π	–	0
0	0	0	+	1
0	0	0	+	1
π	0	0	–	0
π	π	0	+	1
0	π	π	+	1

Decoded data b'(t) from the above table is

1 0 1 1 0 1 1

Table 4c: Choice of the initial bits: 01

b(t)	d(t-T_b)	d(t-2T_b)	d(t)	ϕ(t)
1	1	0	0	π
0	0	1	1	0
1	1	0	0	π
1	0	1	0	π
0	0	0	0	π
1	0	0	1	0
1	1	0	0	π

From the table above the carrier phase shift introduced corresponding to the data stream is

π 0 π 0 π π π 0 π

Table 4d

ϕ(t)	ϕ (t-T_b)	ϕ(t-2T_b)	Sign	b'(t)
π	0	π	+	1
0	π	0	–	0
π	0	π	+	1
π	π	0	+	1
π	π	π	–	0
0	π	π	+	1
π	0	π	+	1

Decoded data b'(t) from the above table is

1 0 1 1 0 1 1

Table 4e: Choice of the initial bits: 10

b(t)	$d(t-T_b)$	$d(t-2T_b)$	d(t)	$\phi(t)$
1	0	1	0	π
0	0	0	0	π
1	0	0	1	0
1	1	0	0	π
0	0	1	1	0
1	1	0	0	π
1	0	1	0	π

From the table above the carrier phase shift introduced corresponding to the data stream is

0 π π π 0 π 0 π π

Table 4f

$\phi(t)$	$\phi(t-T_b)$	$\phi(t-2T_b)$	Sign	b'(t)
π	π	0	+	1
π	π	π	–	0
0	π	π	+	1
π	0	π	+	1
0	π	0	–	0
π	0	π	+	1
π	π	0	+	1

Decoded data b'(t) from the above table is

1 0 1 1 0 1 1

Table 4g: Choice of the initial bits: 11

b(t)	$d(t-T_b)$	$d(t-2T_b)$	d(t)	$\phi(t)$
1	1	1	1	0
0	1	1	0	π
1	0	1	0	π
1	0	0	1	0
0	1	0	1	0
1	1	1	1	0
1	1	1	1	0

From the table above the carrier chase shift introduced corresponding to the data stream is

0 0 0 π π 0 0 0 0

Table 4h

$\phi(t)$	$\phi(t-T_b)$	$\phi(t-2T_b)$	Sign	b'(t)
0	0	0	+	1
π	0	0	–	0
π	π	0	+	1
0	π	π	+	1
0	0	π	–	0
0	0	0	+	1
0	0	0	+	1

Decoded data b'(t) from the above table is

1 0 1 1 0 1 1

Through tables 4a to 4h, it may be noted that the reconstruction is invariant with the choice of the initial bits in the encoded data.

Table 4i and figure 4 show the BER performance comparison between CDPSK and Novel DPSK.

Table 4i: The BER of CDPSK and Novel DPSK

E_b/N_o dB	BER of CDPSK	BER of Novel DPSK
-5	3.65 X10^{-01}	3.11 X10^{-01}
-2.5	2.85 X10^{-01}	2.15 X10^{-01}
0	1.84 X10^{-01}	1.12 X10^{-01}
2.5	8.4 X10^{-02}	3.50 X10^{-02}
5	2.12X10^{-02}	4.36X10^{-03}
7.5	1.81X10^{-03}	1.09X10^{-04}
10	2.27X10^{-05}	1.53X10^{-07}
12.5	9.46X10^{-09}	1.30X10^{-12}

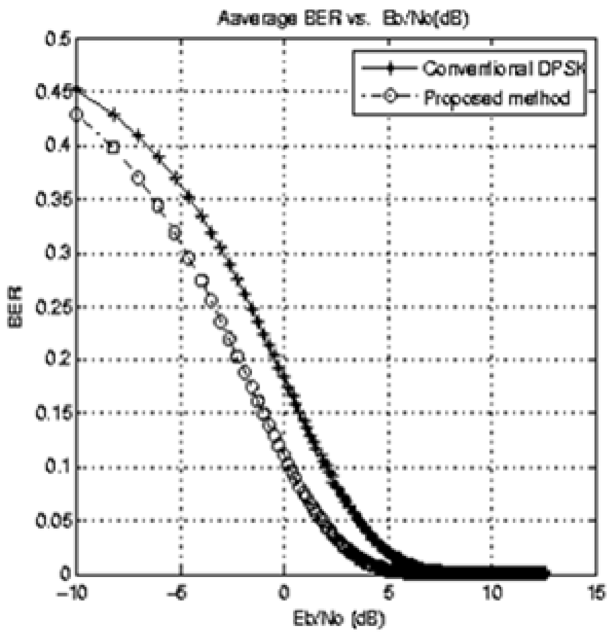

Figure 4. Performances of CDPSK and Novel DPSK

It is now evident from table 4i and figure 4, that Novel coding with the same E_b/N_o exhibits a better error performance than CDPSK.

5 Conclusions and Future work

The novel coding technique proposed in this paper is the most efficient way of achieving better performance in B_T and BER than CDPSK in AWGN channel. Extensive experimentation has been carried out on all choices of initial bits to reveal the correctness of the proposed methodology. The scheme can be used for differential polarization shift keying (DPolSK) in fiber-based and free-space communications. It is not just compatible but complementary too for error control, commonly used in short distance data communications systems such as Automatic Request Repeat (ARQ).

Present paper proposes the coding scheme for two of the many parameters that need further improvements. So we plan to take up future work to design efficient digital modulation scheme and error control strategies at low signal-to-noise ratio.

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